ELECTRIC MOTOR DRIVE SYSTEMS FOR MOTION PICTURE SOUND

One of the final and most important phases in motion pictures is in re-recording. It is then that the many sound tracks (dialogue, narration, music and sound effects) are combined and blended into the release or final sound track.

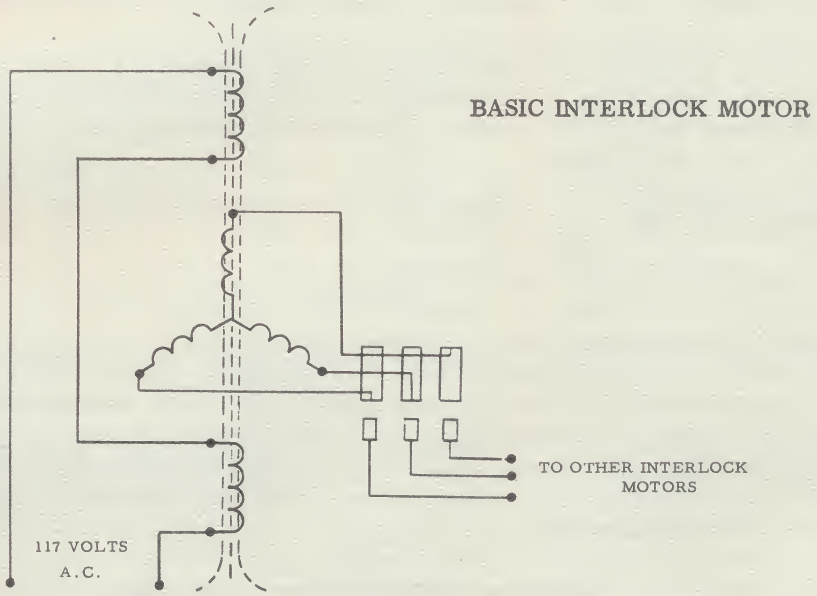
The picture material is spliced to the desired length and, by means of an editing synchronizer, separated reels of music and sound effects are cut to the picture in "sync". Blank or silent leader is added to build out the footage so that the picture, dialogue, music and effects all total the same footage accurate to a sprocket hole. In complicated scenes requiring overlapping of different tracks, more than one reel may be required for each of the added sound materials -- sometimes as many as 20 or 30 separate reels of film all directly related to scenes.

To view and record these separate sounds requires a film playback for each track and some means must be employed to hold them in sync or "lock" from the start mark through the entire film length. Even though each reproducer might be driven from a synchronous motor which would insure constant and common speed, the various transports would not come up to speed together nor would they stop together and reverse if desired.

Interlock motors are the "flexible shafts" electrically connecting a projector and any number of reproducers together. The reproducers are variously called film phonographs, dummies, slaves, or dubbers. Major studios seem to prefer "dummies" or "slaves." While a flexible shaft has been used as an illustrative term, such a mechanical coupling between projectors and several pieces of equipment becomes unwieldly and impractical.

Based on German developments in the late 1800's, interlock motors have been fabricated in sizes from fractional horsepower ranges up to gigantic pieces of machinery used to operate the gates of canals. While the term "Selsyn" is practically a generic name for an interlock motor, this is a trade name of General Electric and its design is identical to other interlock motors.

The interlock motors used to drive radar antennas, and a variety of mechanical devices which must follow in exact step, are powered by normal 117 volt single phase lines. When sound motion pictures were introduced in Hollywood, there was a feeling that the use of three phase power was more positive than single phase. In either case, power is applied to field coils of an induction motor. A second set of coils make up the rotor. Three electrical connections are made to the rotor coil 120 mechanical and electrical degrees apart. Diagrammatically shown as follows:



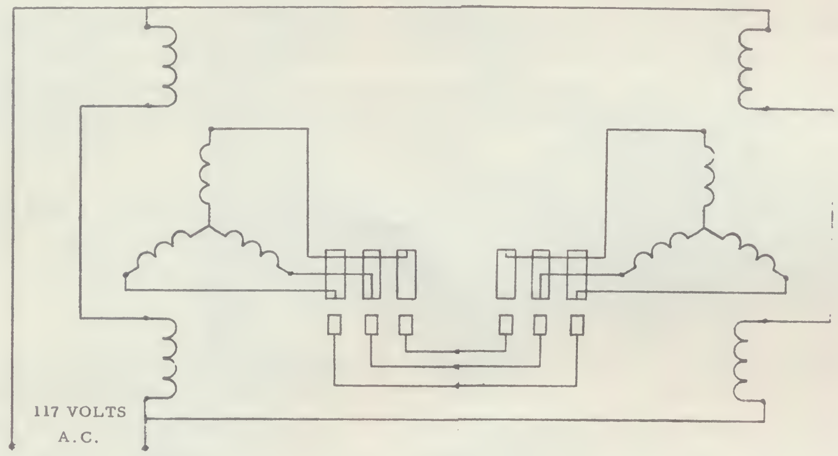
As illustrated, the three rotor connections are brought out to slip rings using brushes to collect the induced voltage. When coils are placed in proximity and coupled by magnetic fields, AC voltage fed to one coil will induce voltage into the other coils. In the design of an interlock motor, the three coils constitute a secondary of

a transformer, however, at no instant can all three coils mechanically align with the primary coils, so a different magnitude of voltage will be induced in each coil.

In the above drawing, it shows a rotor positioned so that the upper of the three coils is aligned perfectly with the input or primary coils and maximum voltage is induced in this coil. The two lower coils, however, are not only misaligned mechanically, but the induced voltages electrically "buck" -- they are out of phase. In this condition, measured voltages across the three slip rings indicates a maximum voltage across one pair of rings and reduced voltages across the other two rings. Rotating the rotor by hand, this voltage rises and falls across each pair of rings as a function of rotation.

Keeping in mind the voltage and phase changes that occur when the rotor of an interlock is turned or driven, it is obvious that when a similar motor is electrically connected to it, there will be a significant interaction between the two motors. Heavy currents will be created in the windings causing rotation to seek a neutral state or identical alignment.

TWO INTERLOCK MOTORS ELECTRICALLY CONNECTED



If one rotor is turned, and the other motor is stationary, the mating voltages from each set of rings become unbalanced and the electrical forces induced cause the second motor to rotate to reach a state of equilibrium. Therefore, if one interlock motor is driven by a motor, the second interlock motor follows.

An interlock motor is one which, when identically connected in parallel to one or more interlock motors, will follow the rotation and speed of the other motors. The only limiting factor is the power output capability. Too heavy a mechanical load causes "slip". Also, if the motor is underpowered, it is "rubbery" and in the case of recording would cause wows or flutter.

SURPLUS MILITARY MOTORS

While the surplus interlock motors, that have been available since the war, are designed as illustrated, they are not exactly suited for film drives for several reasons. They generally were used as instruments to turn meter movements or loads not requiring much power. They also were designed with delicate bearings and brush assemblies made as small as possible to reduce the drag or friction on the movement. Since the interlock motor is an induction motor and, as has been pointed out, draws extremely heavy currents when one rotor is displaced from the alignment of other rotors, the brushes must be capable of handling several amperes. To achieve maximum brush life, it is best to use the same voltage across the rotor as on the secondary. Under these conditions, as an example, a 117 volt secondary would draw less than half the current of a 55 volt secondary with resultant extended life.

Another factor to be considered in surplus interlock motors is the voltage developed across the secondaries or rotors. Some of the rotors are designed for 55 volts, others for 90 volts, and in any case the voltages must match.

The surplus motors were often fabricated for aircraft and other light weight applications wherein the minimum of iron laminations was used. This, coupled with the fact that they are generally only of two pole design, creates a heavy stray flux, or hum, which is very detrimental in magnetic film reproducers. Two pole wind-

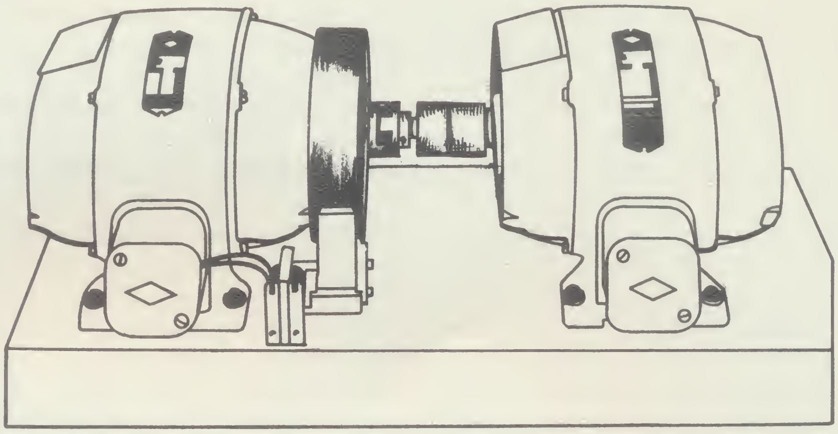
ings have to be carefully and conservatively engineered as each of the two coils span half of the motor circumference and create an intense external flux.

Later in the article, some reasons for two pole, four or more pole windings are established, but for the moment, it is only necessary to assume that the interlock action is the same with any winding.

MOTOR DISTRIBUTORS

The discussion, so far, has covered the ability of an interlock motor to follow one or more interlock motors, but no provision has been made to rotate any of the motors. An interlock motor, by itself, serves only to transfer power and this rotating power must be supplied from an external source.

The original Hollywood installations included a motor-distributor -- i.e., a large synchronous motor to furnish the power coupled to a large interlock motor to energize the other interlock motors in the system.



MOTOR DISTRIBUTOR WITH FLYWHEEL AND MECHANICAL BRAKE

The synchronous motor chosen to drive the distributor has to be capable of carrying the load of a number of dummies and one or two projectors. Such a powerful motor tries to attain synchronous speed in a few revolutions and in doing so could lose "lock" of the interlock motors as well as damage the film. Some means must be used to slow the acceleration or provide a "soft" start.

Some companies providing surplus motors for interlock use a variable voltage transformer which has to be manually controlled. Obviously such an approach restricts remote control of the motors and is limited in power range.

Systems can be evolved using a relay controlled resistance in series with the power leads to the synchronous drive of the motor distributor. The voltage drop across the resistor during the high inrush of current holds the relay contacts open using the resistor for a voltage drop. After the system approaches its running speed and the current drops, the relay falls out in turn closing contacts to short out the resistance. This system works with fair success, but it cannot sense the load accurately.

Centrifugal clutches have been used to couple the drive motor to the distributor to offer a soft start with limited success.

The Stancil-Hoffman motor distributor design answers all of the requirements for soft start and senses the load from a single slave to ten or fifteen slaves and projectors. Designed for either single or three phase drive motors, the system consists of an induction coil around a floating metal rod or armature. The coil is wound with heavy wire around a hollow tube mounted in a vertical position and is connected in series with the power leads of the synchronous motor. During the high inrush of current at the start, the metal armature is drawn within the coil center. The resultant reluctance limits the current for the motor so that it comes up to speed relatively slowly. As soon as the starting current drops, the armature in the coil falls free leaving only the negligible resistance of the copper wire in series with the motor. Obviously, the high "inrush" current exists until the motor attains sync speed, and this time element is dependent on the load it must bring to this speed. In other words, the delayed or soft start is predicated by its load or the number of interlock motors in the chain.

When interlocking a group of units, it is not only desireable to bring them up to speed at a constant rate, but have them slow down in the same manner so as not to lose the interlock. The Stancil-Hoffman motor distributor uses a 20 pound flywheel to provide inertia effective in starting and stopping. A solenoid operated mechanical brake is set against the flywheel to slow down the distributor at a predetermined rate. The brake shoe is pulled clear when the drive motor is energized and automatically sets when the motor circuit is opened. Under these conditions, the film in the projector or on the dummies is never abused and the interlock cannot be broken due to a too fast start or stop.

Stancil-Hoffman furnishes such installations which will handle ten or more slave interlock motors. Depending on the power source available, the synchronous motor may be 117 volts single phase, 230 volts single phase or 230 volts three phase, 50 or 60 cycles. The distributor is chosen to match the type of interlock motors and as such, may be 117 volts single phase or 230 three phase.

Large 35mm projectors are nominally powered with 1/6 to 1/3 horsepower motors and require a very heavy interlock drive and power source. Often, an interlock motor is added to the projector letting it become the "motor distributor" to drive the dummies. While the projector may not run at exactly 24 frames per second, since its standard drive motor is not synchronous, this "piggy back" arrangement is perfectly satisfactory for double system viewing as sound and picture are in sync.

Incidentally, interlock motors are not generally rated in horsepower. A horsepower rating is arrived at by measuring the output torque of a motor at a certain speed. For example, a motor operating at 900 RPM might develop 16 ounces of pull on a pulley diameter of 3 inches. If the motor developed the same pull at 1800 RPM, it would be rated at twice the horsepower. The horsepower rating must, therefore, be given at its running speed. Interlock motors are used at many different speeds and are generally ordered for the particular job at hand.

ELECTRICAL CONNECTIONS

In practice, three phase interlock motors are the most efficient. Three phase, by its inherent nature, is a "rotating field" and interlock motors in a three phase connection tend to rotate in the direction of this rotating field. When using a number of single phase interlock motors, there is no preferable interconnection. The three wires between the different motors in the system are merely connected so that the rotors turn the required direction. If they do not, changing connections of any two of the three wires will change the direction of rotation.

When using three phase interlock motors, care must be taken to properly interconnect the three wires of the secondaries. The procedure is to apply power to the input leads of a motor and, with the motor free from any mechanical loads, the rotor leads are tied together causing the motor to operate as an induction motor. The direction of rotation is noted, and if it is opposite to what is required in the equipment, two leads of the <u>input</u> three phase leads are reversed. These connections are noted and each motor is tested and the leads are identified in this fashion. If this procedure is not observed, the motors will heat and tend to "run away". Stancil-Hoffman's three phase interlock motors are numerically coded so that like numbers are mated if all are to turn in the same direction.

SYNCHRONOUS MOTORS

While this discussion is about interlock motors, synchronous motors enter as they must provide the motive power. Regardless of whether the motor is powered by single or three phase, the basic principle of operation is the same. A rotating field is established in the stator and by magnetization it repels or chases the rotor around at a constant speed of rotation. The type of synchronous motor is generally derived by its rotor construction, and two types are of immediate interest to us.

The salient pole motor consists of a rotor made up of coils, or most usually, copper bars shorted at each end. Mechanically, the rotor is broken up into 2, 4 or more sections and these are called salient poles. The shorted bars, being in the magnetic field of the stator have induced currents which set up opposing fields to the stator -- hence, rotation.

The hysteresis rotor is made up of a homogeneous sleeve or cylinder without any salient poles. Being of a material having a cobalt content with a magnetic retentivity, the rotor is magnetized when the stator is energized and the resultant magnetic poles are repelled by the stator causing rotation. If the load imposed on the motor is too great, the AC field "erases" the poles and when the load is released, new poles are magnetized. Also each time the motor starts it establishes new poles.

The speed of a synchronous motor is dependent on the line frequency and number of poles. Considering the line frequency of 60 cycles, this means that every second there are 60 alternations of current from negative to positive. When the 60 cycle power is connected to a stator winding, the negative/positive cycling will cause north/south magnetic poles at a 60 cycle rate. Placing a magnet in this field would cause 60 revolutions a second or 60 x 60 = 3600 revolutions per minute. As we considered only a single north/south combination, we say it has two poles. The speed of a two pole motor on 60 cycles is 3600 RPM. Using 50 cycles the speed would be 5/6 of this or 3000 RPM.

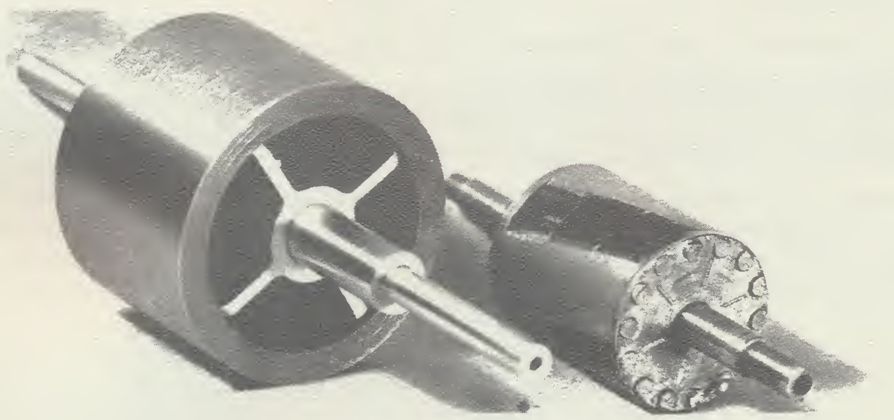
Suppose four coils are used in the stator and connected alternately so that when energized, they present a north/south/north/south magnetic field in the stator. The result is a four pole motor. A magnet placed in this field would be repelled as before, but instead of making one revolution per cycle, it would take two cycles for a revolution. The speed would be 30 revolutions per second or 1800 RPM.

In practice it is necessary to bring the rotor up to speed as it cannot accelerate from a dead start to its running speed in one cycle (1/60 of a second). A rotating field must be created to start the rotor and have it "lock in" with the line frequency.

Earlier, it was stated that 3 phase power is inherently a rotating field. Each second there are 3 progressive alternations 120 degrees apart. The magnetic field of a 3 phase stator automatically repels a rotor into rotation.

Single phase power merely alternates 60 times, and a magnet in such a field remains stationary and buzzes.

Two procedures are used to create rotation. The first is to use two coils for each pole. When wound, the coils are displaced in the stator by mechanical 90°. The second procedure is based upon the fact that when power is applied to a load through a capacitor, the load is 90 electrical degrees away from the power source. Electrically connecting the second coil through a capacitor provides a 180 degree shift (90 degrees electrically and 90 degrees mechanically). A rotating field is now established and this procedure is often called a capacitor "start and run" motor.



HYSTERESIS AND SALIENT POLE ROTOR

Illustrated are both types of rotors showing both the construction and comparative sizes.

MULTI SPEED HYSTERESIS MOTORS

Recalling the salient pole motor, it is obvious that a four pole rotor could only run at one speed because it is mechanically built up of 4 discrete poles, but the hysteresis rotor may be magnetized in any number of poles depending only on the stator design. If the stator had two sets of windings, — one 2 pole and one 4 pole — the hysteresis rotor could be driven at either 3600 RPM or 1800 RPM. Two speed hysteresis are used on Stancil-Hoffman equipment for 90 FPM and 45 FPM or conversion kits from 35mm to 16mm.

Not only does the hysteresis motor have the handy advantage of simple multispeed operation, but also it is a mechanically quieter motor than the salient pole design since the hysteresis rotor is a solid mass rather than discrete conductors and poles.

COMPATIBILITY OF HYSTERESIS MOTORS WITH INTERLOCK MOTORS

Our principle interest in hysteresis motors, in reference to interlock motors, is the capability of the rotor being magnetized at any angular point of rotation. Its poles are not permanently magnetized or established

until it is up to sync speed. The salient rotor, as pointed out previously is mechanically constructed to have fixed areas or permanently fixed poles. A two pole motor will lock in sync at only one position in the 360 degrees of rotation.

Visualize what happens when a number of pieces of equipment which are driven by salient pole motors are all interlocked together. Unless they are exactly mechanically phased, each motor tries to seek its locked point of rotation and motors fight each other resulting in overloading and wow because of hunting.

The hysteresis motors, on the other hand, all compatibly lock together when up to speed. And better yet, when they are interlocked with a distributor or projector which uses a salient pole sync drive, the hysteresis motors fall in step with the point of lock of the synchronous motor without bucking.

For the above reasons, only hysteresis motors are used in Stancil-Hoffman film recorders. Not only do they possess the smoothness and compatibility required, but they are conservatively designed with reserve power to drive projectors, remote footage counters and other interlocked machinery through interlock motors. Each film recorder is, in effect, a motor distributor system.

Stancil-Hoffman has produced a number of motors including both the hysteresis drive motor and the interlock motor in the same housing. This assembly is somewhat more costly than the individual synchronous motors and interlock motors and restricts the flexibility. Admitting that two separate motors take up slightly more room it is generally conceded to be a better practice than a combination motor.

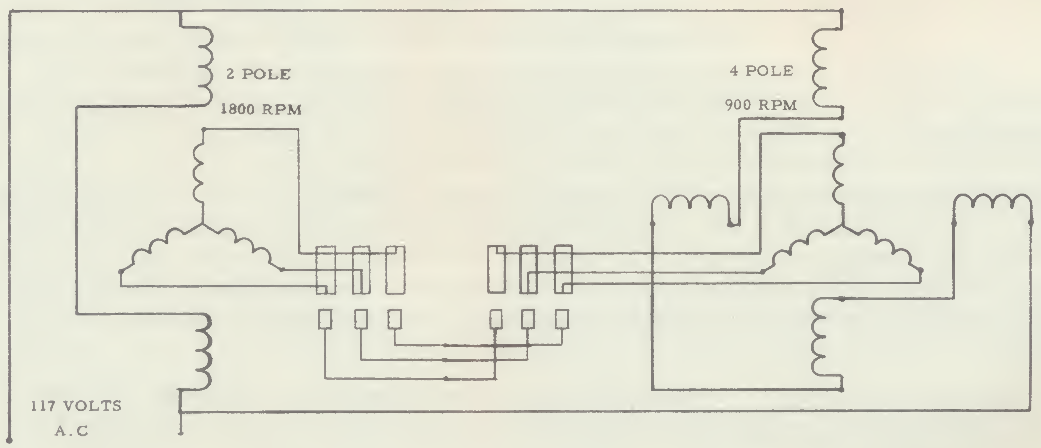
CHOICE OF POLES IN INTERLOCK MOTOR

The discussion of speed and poles brings forth another factor in the selection of interlock-motors. Being induction devices, they lose their power capability when they are driven beyond a certain speed. For example, there would not be any induction in a 4 pole interlock driven at 1800 RPM as this is the synchronous speed of a 4 pole design on 60 cycles. The rotor would be following the line frequency pulsations exactly in step and no induction could take place nor could any power be developed. For this reason, a 2 pole motor is used at 1800 RPM. 4 pole motors are used up to speeds of 1500 RPM.

While the 2 pole motor will operate satisfactorily at the lower speeds, it is not generally used because of the induced hum it creates in the playback equipment

INTERLOCK ELECTRICAL GEARING

In addition to acting like a "flexible shaft" between two moving bodies, interlock motors can also function as electrical gears. As has been pointed out, when two identical interlock motors are electrically connected, rotating one shaft will cause the shaft of the second motor to exactly follow direction and speed. However, if one of the two motors has more than the 2 poles, it will follow at half speed or slower depending on the number of poles.



INTERLOCK MOTORS TIED TOGETHER FOR 2:1 SPEED RATIO

Examples in film recorders would be the 90 feet per minute or 45 feet per minute speed change.

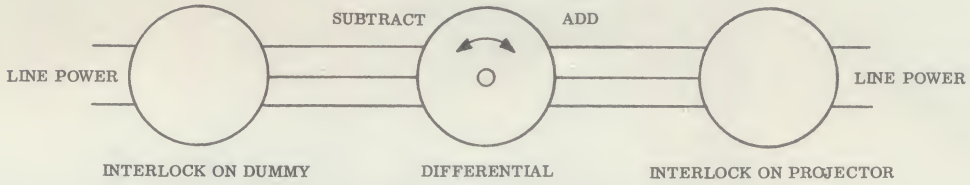
Illustrated is a 2 pole motor connected to a 4 pole wherein an electrical gear ratio of 2:1 is produced. In Hollywood, much of the original dialogue is now recorded at 45 feet per minute. For transfer and "dailies" it is often necessary to interlock with projectors or other equipment operating at 90 feet per minute. The 2 pole, 4 pole hookup provides the 2:1 speed ratio (90 FPM to 45 FPM). By installing both a 2 pole motor and 4 pole motor on the same dummy, either speed may be selected without changing any mechanical part.

A novel application of an electrical gear is covered by a Stancil patent #2,267,844. Synchronizing and interlock has always been a challenge, but it was a far greater challenge using discs instead of present magnetic film or tape. In this instance the problem was to interlock a turntable and an amateur motion picture camera for sync motion picture production. The electrical gear was an ideal solution.

By simply placing a multi pole "transmitter" interlock drive on the turntable and electrically connecting it to a two pole interlock motor on a camera, a speed ratio of 12:1 was obtained as well as holding absolute interlock. In this case, 12:1 was chosen because for conservation of film for amateur applications we were only concerned with 16 frames per second instead of the usual sound speed of 24 frames per second. The step up could be any ratio desired — in this instance the turntable was 78 RPM and the camera intermittent projector speed would be 12 times this, or, for simple figures it could be 80 RPM to 960 RPM. (24 frames equals 1440 RPM)

DIFFERENTIAL SPEED CHANGERS

Stancil-Hoffman has been called upon many times to provide interlock motors for double system projection wherein picture and sound are released separately, — such as at a "preview." There can be no worse situation than sound out of sync, and the simple insurance we have provided is the "differential" interlock.



The differential interlock is electrically connected between the projector interlock motor and the sound reproducer interlock, the differential is rotated in one direction to subtract frames and in the other direction to add frames. If through improper threading or splicing, the sound should get out of sync, it is only necessary to turn the differential to bring the film back in sync without having to stop and rethread.

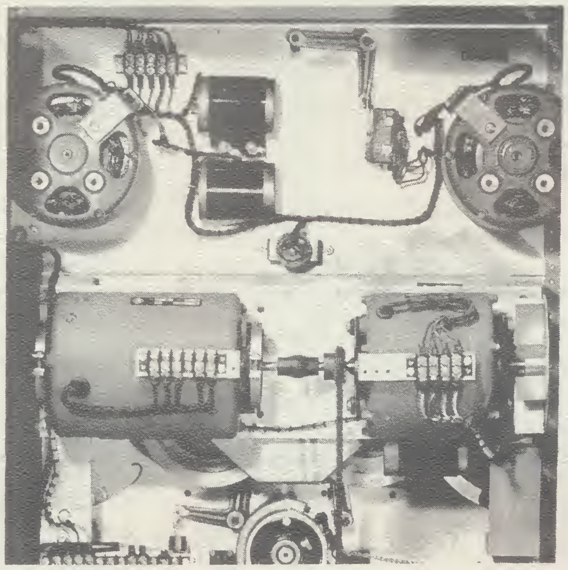
A complete projection editing system console was provided for 20th Century Fox to remotely control six 3 track dummies and two 35mm projectors. Of note in the design are differentials having dials calibrated in frames so that the film editor can detect and correct any out of sync condition and know by the dial settings how many frames a film is out of sync.

The differential can offer another valuable function. In TV production many foreign countries on 50 cycle power use a TV intermittent of 25 frames per second instead of our standard movie speed of 24 frames per second, resulting in more sound footage per second. The TV picture can be electronically interlaced and corrected to

24 frames, but the sound must be rerecorded to match the film's speed. Rather than be forced to buy separate equipment for the two different speeds, or have to make mechanical changes each time a conversion would be required, the differential solves the problem. The interlock motors on standard dummies are connected through the differential. By slowly driving the differential shaft from a synchronously driven gear box, a speed ratio of 25 to 24 is obtained. For standard speeds on a 1:1 ratio (25 FPM to 25 FPM or 24 FPM to 24 FPM) the differential remains stationary and the differential acts as a transformer with 60 cycles in and 60 cycles out. However, when the differential is rotated at a certain speed in one direction with an input of 60 cycles, it provides 57.5 cycles output. Driving it at the same speed in the opposite direction, it would produce 62.5 cycles. Another name for the differential is "frequency changer."

Not only can the 25 frame to 24 frame speed change be accomplished in this fashion, but other speed changes may be handled such as from 50 cycles to 60 cycles.

INTERLOCK AND HYSTERESIS SYNC MOTORS CHAIN COUPLED TO GEAR BOX AND CLUTCH



DRIVE SYSTEM OF S7 FILM RECORDER

The top two motors are "torque" reel motors. Like synchronous motors, these motors have a capacitor start and run rotating field, but the rotor is made up of a special metal cylinder. When the rotor is stationary, maximum induction is created with resulting maximum flux or torque. As soon as the rotor rotates it starts to "catch up" with the rotating flux and in so doing, the rotor cuts less lines of flux resulting in less torque, -- the faster it rotates, the lower its torque.

This torque characteristic is essential in reeling film. The take up reel of a recorder starts out with a minimum film diameter, demanding minimum torque. Also, it must rotate its fastest speed. As the diameter builds up so does the torque requirement. The motor senses the speed and furnishes the required torque so that the pull or tension on the film is practically constant from beginning to the end of a reel. Further, the rotor has a smooth surface with no defined poles as we cannot tolerate "cogging" in a torque motor which results in flutter.

When the S7 is ordered with an interlock motor, it is mounted in line with the hysteresis synchronous motor. As shown, this forms a "junior" motor distributor having reserve power to drive a 16mm projector through interlock. The synchronous motor is on the right.

STANCIL-HOFFMAN MOTORS

The Stancil-Hoffman Corporation started production of magnetic motion picture recorders in 1948. It was the aim of the corporation to be a one source supply of all accessory items to build up a complete recording facility. The one weak area turned out to be both interlock and synchronous motors. Since there was not a supplier in the country who had the full line of motors required, the corporation designed and has been fabricating these motors for over 15 years. Their performance and extended life has been most gratifying.

The Model S7 Film Recorder, which uses these motors, is the only film transport available incorporating interlock systems not requiring a motor distributor system. The many models of motors available permit the use of the Model S7 for any of the single or multiple film speeds and the finest operation without compromise. Recognizing the unavailability of these special motors, the corporation will furnish these motors to work with any existing equipment.